IMAGE OR VIDEO PROCESSING

Field of the Invention

This invention relates to a method of image or video processing in, for example, a portable electronic device such as a mobile communication device. The invention is applicable to, but not limited to, a display device used in a portable electronic device, such as a personal digital assistant (PDA) or mobile phone, where battery power to operate and refresh the display with new images is limited.

Background of the Invention

Future generation mobile and fixed communication systems are expected to provide the capability for video and image transmission, as well as the more conventional voice and data services. As such, video and image communication will become more prevalent, and improvements in video/image compression technology are likely to be needed in order to satisfy the consumer demand within the available communication bandwidth.

Furthermore, as mobile users wish to access ever more services whilst on the move, such as text strings, text messages, email, images and/or video, similar improvements are required for display technologies. Given the current user trend towards desiring smaller, lighter and more portable wireless communication devices, the improvement to displays is considered a particularly key market differentiator for manufacturers.

In the field of portable electronic devices capable of displaying images, for example by way of liquid crystal displays (LCDs), it is often necessary for the image data to be pre-processed prior to being displayed, or prior to being provided to the device. One reason for such pre-processing may be due to the initial image data being unsuitable for the particular display of the device.

Alternatively, the display may be capable of operating in more than one mode, for example a first mode of operation for displaying high quality images and a second mode of operation for reduced power consumption. In such a dual-mode situation, although the initial image data may be suitable for the first mode of operation, it may be unsuitable for the second mode of operation.

One known method of defining an image using binary data is for the image to be divided up into pixels. Each pixel is then defined by a string of, for example, sixteen bits. For colour displays using red-green-blue (RGB) colour definition, pixels have individual fields allocated for three components, namely one for each primary colour. A common example is to define a 16-bit pixel word with, for example, 5 bits allocated for red coloured pixels, 6 bits allocated for green coloured pixels and 5 bits allocated for blue coloured pixels. This allows a range of 65,536 (2^{16}) colours to be used when displaying an image.

However, many displays are only capable of displaying a range of, for example, 512 (2^9) colours, defined by 9 bits where each of the primary colour components red, green and blue are defined by three bits each.

Therefore, before the image can be displayed, it is necessary to process the image data such that the data representing each pixel is converted from 16 bits down to 9 bits.

Reducing the number of bits used to represent each pixel has the advantage that the amount of memory required to store the image data is reduced. Furthermore, when transmitting the image data over a bandwidth-limited network, for example over a wireless cellular communications network, a public switched telephone network (PSTN), computer network, infrared interface, etc., the time taken to transmit the data is reduced.

A known method for reducing the number of bits used to represent a pixel from sixteen to nine is known and referred to as truncation, or rounding down. With this method, the number of bits representing each colour component is simply reduced to three bits by discarding the least significant bits (LSBs) of each colour component. Thus, for each pixel, the sixteen bits are divided into the three parts representing the three colour components red, green and blue. For the five bits representing red, the two of least significance are discarded, leaving only the three of most significance. For the six bits representing green, the three bits of least significance are discarded, leaving only the three of most significance. For the five bits representing blue, the two bits of least significance are discarded, leaving only the three of most significance. The resulting nine bits, three for each colour components, are then combined to define the entire pixel.

However, although this method provides a simple means of reducing the number of bits representing each pixel from sixteen to nine, the quality of the resulting image is noticeably affected, as bits that determine a pixel's colour are discarded. Although the poor image quality is partly due to the number of colours available for displaying the image being reduced from 65,536 to 512, the deterioration of the image is increased due to data being discarded and lost for each colour component during truncation. In particular, such image deterioration causes significant visible contouring of the image, which is undesirable to a user viewing the display.

Thus, a need exists for an improved image processing mechanism for a display, wherein the abovementioned disadvantages may be alleviated.

Statement of Invention

In accordance with a first aspect of the present invention, there is provided a method for processing image or video data for a display, as claimed in Claim 1.

In accordance with a second aspect of the present invention, there is provided an image or video processing system, as claimed in Claim 10.

In accordance with a third aspect of the present invention, there is provided a display driver for refreshing an image of a display device, as claimed in Claim 11.

In accordance with a fourth aspect of the present invention, there is provided a storage medium storing processor-implementable instructions for controlling one or more processors, as claimed in Claim 12.

In accordance with a fifth aspect of the present invention, there is provided an image or video communication device having a display, as claimed in Claim 13.

In accordance with a sixth aspect of the present invention, there is provided a video or image communication device, as claimed in Claim 14.

Further aspects of the present invention are as defined in the dependent Claims.

In summary, an image communication device and method for processing image or video data for a display are described whereby a bit truncation process is improved by reusing discarded bits to improve the quality of the image generated from non-discarded bits. The improvement is achieved by using the discarded bits to modify the bit values of the non-discarded bits of pixels or blocks of pixels.

Brief Description of the Drawings

Exemplary embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 shows a block diagram of a battery-powered wireless subscriber unit, adapted to support the inventive concepts of the preferred embodiments of the present invention;

FIG. 2 illustrates a block diagram of a liquid crystal display (LCD) control/driver circuit, adapted to support the inventive concepts of the preferred embodiments of the present invention;

FIG. 3 shows a pixel array representing an image;

FIG. 4 illustrates data representing an image formed into an array of pixel blocks in accordance with the preferred embodiments of the present invention;

FIG. 5 illustrates data representing an image in a block from the array of pixel blocks of FIG. 4;

FIG. 6 illustrates pixel data of an image for one pixel;

FIG. 7 illustrates pixel data of a colour component, where the data is to be truncated in accordance with the preferred embodiments of the present invention;

FIG. 8 illustrates blocks of pixel data of a colour component, where non-discarded bits are modified using discarded bits in accordance with the preferred embodiments of the present invention; and

FIG. 9 illustrates a flowchart of the preferred embodiments of the present invention.

Description of Preferred Embodiments

The preferred embodiment of the present invention is described with reference to a portable cellular phone capable of operating in, for example, a current or future generation of wireless cellular technology. However, it is within the contemplation of the present invention that the inventive concepts described herein are equally applicable to any other video or image display device, such as a personal data assistant (PDA), a portable or mobile radio, a laptop computer or a wirelessly networked personal computer (PC) or indeed any other digital device having a display to support video/image transmissions.

Referring first to FIG. 1, there is shown a block diagram of a cellular subscriber unit 100 adapted to support the inventive concepts of the preferred embodiments of the present invention. The cellular subscriber unit 100 contains an antenna 102 preferably coupled to a duplex filter, antenna switch or circulator 104 that provides isolation between receiver and transmitter chains within the subscriber unit 100.

The receiver chain, as known in the art, includes scanning receiver front-end circuitry 106 (effectively providing reception, filtering and intermediate or base-band frequency conversion). The scanning front-end circuit 106 is serially coupled to a signal processing function 108. An output from the signal processing function 108 is provided to a suitable output device 110, such as a screen or flat panel liquid crystal display. The screen or flat panel display 110 includes a display driver circuit 111.

The receiver chain also includes received signal strength indicator (RSSI) circuitry 112, which in turn is coupled to a controller 114 for maintaining overall subscriber unit control. A timer 118 is operably coupled to the controller 114 to control the timing of operations (including transmission or reception of time-dependent signals) within the cellular subscriber unit 100. The controller 114 is also coupled to the scanning receiver front-end circuitry 106 and the signal processing function 108 (generally realised by a DSP) for receiving a transmitted video or image signal.

The controller 114 may therefore receive bit error rate (BER) or frame error rate (FER) data from recovered information. The controller is also coupled to a memory device 116 that stores operating regimes, such as decoding/encoding functions and the like.

In accordance with the preferred embodiment of the present invention, the processor 108 performs bit-truncation on pixel blocks of a received image, preferably on a per colour basis. In cooperation with the display driver circuit 111, the processor 108 and display driver 111 have been adapted such that any bits to be discarded in the truncation process are reused to dynamically adapt a respective colour of a pixel in an image refresh operation. In particular, the bits that are to be discarded are reused to modify one or more bits that survive the truncation process to enable a more accurate colour shade to be displayed.

It is within the contemplation of the invention that the inventive concepts described herein apply equally to images or video received by the communication unit, or previously stored within the communication unit for subsequent display.

FIG. 2 illustrates a block diagram of a liquid crystal display (LCD) control/driver circuit 200, adapted in accordance with the preferred embodiment of the present invention. A microprocessor, for example the microprocessor 108 of FIG. 1, initialises an LCD controller 140 and a DMA controller 220 by way of control registers 132. The microprocessor 108 manages the contents of image memory 210 via an address bus 134 and a data bus 136.

The LCD controller 140 is also connected to an LCD panel 110 by way of a timing link 142 that provides, inter-alia, timing signals such as horizontal (H)-sync, vertical (V)-sync and pixel clock. The DMA controller drives pixel data bus 144, by way of a data latch 240, to provide pixel data to the LCD panel 110. For the illustrated embodiment there is also provided a connector 140 between the LCD controller 140 and the LCD panel 110. The LCD panel 110 includes an LCD display and control circuitry (not shown).

The LCD controller 140 also provides timing control signals to the LCD panel 110, the DMA controller 220 and the data latch 240 to coordinate the retrieval and making available of pixel data. The DMA controller 220 retrieves pixel data for the image to be displayed from the memory device 210 via address bus 134 and data bus

136. *The pixel data retrieved from the memory is then* passed to a data latch 240.

The LCD panel 110 receives the timing signals provided by the LCD controller 140 and, in response to the timing signals, retrieves the data for each pixel. In accordance with the preferred embodiment of the present invention, such pixel data contains a truncated number of bits for each primary colour, with the discarded bits in the truncation process having been used by the microprocessor 108 to modify the truncated bit sequence. The LCD panel 110 then systematically displays the corresponding image one pixel at a time.

It is envisaged that the original image data could be obtained by the microprocessor 108 and processed, the processed data then loaded into the memory 210 for displaying immediately. However, a preferred alternative, in order to prevent delays in displaying images, is that the original image data is processed, by microprocessor 108 (or another processor) and stored in an area of memory, such as memory element 210 (or another memory element) for later displaying. When the processed image is to be displayed, assuming that it is stored in memory element 210, the microprocessor 108 may simply initialise the LCD controller 140 and DMA controller 220 to locate the processed image data. Alternatively, if the data is located in another memory element the microprocessor 108 fetches the data, stores it in memory element 210 and then initialises the LCD controller and DMA controller.

It will be appreciated that the LCD control/driver circuit 200 illustrated in FIG. 2 is only an example of a suitable LCD driver circuitry apparatus, and that any other suitable circuitry known may alternatively be adapted to facilitate and perform the inventive concepts described herein.

It is within the contemplation of the invention that the microprocessor 108 and/or microprocessor memory element 210 of the cellular subscriber unit 100 (or other video/image device) may be re-programmed with an algorithm (such as that described with respect to FIG. 9) supporting the inventive concepts of the present invention, as described below. More generally, according to the preferred embodiment of the present invention, such re-programming to dynamically re-use discarded bits from a bit-truncation process may be implemented in a respective cellular subscriber unit 100 (or other video/image device) in any suitable manner. For example, a new memory chip or processor may be added to a conventional cellular subscriber unit 100 (or other video/image device). Alternatively, such re-programming may be configured to perform discarded bit reuse on an image or video file and saved for displaying at a later time.

Alternatively, existing parts of a conventional cellular subscriber unit 100 (or other video/image device) may be adapted, for example by reprogramming one or more processors therein. As such, the required adaptation may be implemented in the form of processor-implementable instructions stored on a storage medium, such as a floppy

disk, hard disk, programmable ROM (PROM), RAM or any combination of these or other storage media.

The image data may be processed according to the present invention by the microprocessor 108 prior to being stored in the associated memory 210. In this way, the pixel data requires no further processing before being made available to the LCD panel 130. However, it is within the scope of the present invention for the processing to be carried out prior to being received by the microprocessor 108 and stored in the memory 210.

For display technologies, it will be appreciated that the image data initially provided to the device containing the display, for example the LCD panel 110, may be in a format unsuitable to display the image correctly. Hence, in accordance with the present invention the image data may require a truncation process prior to being provided to the display.

For example, let us assume that data representing an image 300 defines the characteristics of each pixel 310 of the image 300, as illustrated in FIG. 3. Sixteen bits define each pixel of the initial image data 300, where the sixteen bits are divided into three primary colour components: five defining red; six defining green; and five defining blue. In order for the image to be displayed on say, the LCD panel 110 of the cellular subscriber unit 100, let us assume that it is necessary for the data to be converted such that characteristics of each pixel are defined using a reduced number of bits, for example nine bits.

It is envisaged that the characteristics of each pixel may need to be defined in a reduced number of bits due to a need for the display to operate in a reduced power consumption mode, for example to reduce the number of data-line transitions. Alternatively, the display may be of a design that cannot handle the image data in the sixteen-bit format, but may be able to handle, say, a reduced nine-bit pixel characteristic format.

In accordance with the preferred embodiment of the present invention, and as illustrated in FIG. 4 and FIG. 5, the image data is preferably divided into blocks 420, which for the illustrated embodiment each comprise four pixels 410 arranged two-by-two. The pixel data is converted from sixteen bits per pixel, to nine bits per pixel a block at a time, in the following manner.

FIG. 6 illustrates the pixel data of the initial image data for one pixel, comprising sixteen bits. The first five bits (R0 to R4) define the red colour component of the pixel, the next six bits (G0 to G5) define the green colour component of the pixel, and the final five bits (B0 to B4) define the blue colour component of the pixel.

The pixels 410 within the block 420 are divided into their respective colour components, and rounded down (or truncated) to three bits to provide the baseline values 720, as illustrated in FIG. 7. In this manner, for each colour component, the respective number of lesser significant bits are discarded, for example R3 and R4 for the red colour component.

In contrast to known truncation mechanisms, the preferred embodiment of the present invention utilises these discarded bits 730 of each pixel within the block. In particular, the discarded bits 730 of each pixel are subsequently used to determine an offset for the respective colour component. In turn, the offset is used to determine the number of pixels within the block for which the baseline value of that colour component is to be corrected.

In this way, the colour component baseline value may be obtained, for example in the same manner as for a known truncation method. However, advantageously, the colour data within the block may be improved by modifying the colour component baseline value in response to the binary values of the discarded bits 730. In this manner, the discarded bits 730 are effectively reused and redistributed among the pixels.

For example, the discarded bits 730 of each pixel within the block, for example R3 and R4 for the red colour component are added together to produce the offset for that colour component. This offset value is subsequently divided by n^2, where n is the number of bits discarded 730 for each pixel to obtain the baseline values. Therefore for the illustrated embodiment for the red colour component, n^2 equals four.

The preferred embodiment of the present invention is described with respect to bit manipulation in a binary format. Consequently, the correction value is preferably set to 1, such that the three-bit baseline colour component value is incremented in a binary format by '1'.

In a yet further preferred embodiment of the present invention, in order to obtain the baseline values for a colour component within the block, the colour components of the initial pixel data for that block are added together and divided by the number of pixels to provide an average colour component value. This average colour component value is then truncated to three bits to provide the baseline value for all pixels within the block. Thus, all pixels within the block comprise the same baseline values derived from average colour component values. The bits discarded through truncation of the average colour component value are subsequently used to obtain the offset value.

Since the discarded bits 730 are discarded from the average colour component value across a number of blocks of pixels, the values of the discarded bits (n) will be the same for each pixel in a block, due to the use of an average colour component. In determining the number of pixels to be "corrected", an offset value is calculated, which is the value(s) of discarded bits for each pixel added together. Therefore, when using the average colour component, the offset value equates to the binary value of the discarded bits 730 from the average colour component value (i.e. from one pixel) multiplied by the number of pixels in the block. If we define the number of pixels as "X" and the value of discarded bits from the average as "VAL", the offset value may be written as:

$$OFFSET = X * VAL \qquad [1]$$

Once the offset value is calculated, it can be used to determine the number of pixels to "correct", by dividing it by n^2, where n is the number of bits discarded. Thus:

$$\text{No. of pixels to be corrected} = X*VAL/n^2 \quad [2]$$

For the described example, both X (number of pixels) and n^2, equal '4' (namely 2*2). Therefore, and advantageously, X and n^2 are configured to have the same value and thereby cancel each other out, leaving 'VAL'.

Therefore, as illustrated in FIG. 8, when the discarded bits 730 have the binary values '00' in configuration 810, the baseline value for none of the pixels is corrected. Where the discarded bits have the binary values '01' in configuration 820, the correction value is added to the baseline value for one of the pixels in the block. Where the discarded bits have the binary values '10' in configuration 830, the correction value is added to the baseline value for two of the pixels in the block. Where the discarded bits have the binary values '11' in configuration 840, the correction value is added to the baseline value for three of the pixels in the block.

The preferred embodiment of the present invention implements this as follows, where the least significant of the discarded bits has a value of '1', which for the red colour component is R4, the correction value is added to the baseline value for the bottom right pixel. Where the LSB-but-one has a value of '1', which for the red colour component is R3, the correction value is added to

the baseline value for the bottom left pixel and the top right pixel.

In accordance with the preferred embodiment of the present invention, if the three-bit baseline value (R0 to R2) has a binary value of '111', the correction value is not added to the baseline value, in order to prevent bit-rollover. In this manner, a more accurate representation of the colour to be displayed is achieved.

In areas of the image where there is a relatively large amount of detail, it is preferable not to take the average colour component value to obtain the baseline value of the colour components, since this will affect the detail of the image. In fact, the problems encountered through truncation such as contouring are generally not visible in areas of relatively high detail. Hence, in accordance with the preferred embodiment of the present invention, it is envisaged that the above-described inventive concepts are applied in regions of low detail.

In order to determine when a block of pixels is part of an area of high or low level of detail, the luminance range for that block can be used. This may be achieved by obtaining the luminance value for each pixel within the block. If the range of these luminance values is greater than a certain threshold, for example '2', then the block of pixels may be determined as residing within an area of relatively high detail. In this scenario, normal truncation may be used. Otherwise, the method of the present invention is used to convert the pixel data from say, sixteen bits to nine bits.

The luminance value (L) from RGB colour components for each pixel is preferably obtained using the following equation, by the international standard (ITU-R BT.601):

$$L = 0.229R + 0.587G + 0.114B \qquad [3]$$

Where:

R is the decimal value for the red colour component of the pixel,

G is the decimal value for the green colour component of the pixel, and

B is the decimal value for the blue colour component of the pixel.

The resulting value for 'L' is generally used by monochrome monitors to represent an RGB colour. Each pixel in the block provides its own luminance value. The greater the range of these values, the more detail there is likely to be in the block. Hence, in the preferred embodiment of the present invention, following extensive testing on 'text' images by the inventors of the present invention, a threshold value of "L=2" has been selected.

Referring now to FIG. 9, a flow chart 900 of the preferred method of implementing the present invention on a block of pixels, is illustrated. It is envisaged that the hereinafter method steps may be performed, for example, by microprocessor 108 of cellular subscriber unit 100. In the preferred embodiment, the pixel data is being converted from say, sixteen bits to nine bits.

The method starts in step 905 by extracting the colour components for each pixel in the block. For the red and blue colour components, of the preferred 16-bit embodiment of the present invention, all five bits are obtained. However, for the green colour component, which comprises six bits, only the first five (more significant) bits are obtained. The sixth least significant bit is preferably omitted, in order to simplify the process.

Next the luminance for each pixel is preferably calculated, as shown in step 910. If the luminance range is greater than a predetermined threshold in step 915, for example greater than a luminance value of '2', the pixel data for each pixel in the block is truncated in the normal manner, as in step 920. The process is then repeated for the next block of pixels, as shown in step 925.

If the luminance range is less than or equal to the threshold in step 915, for each colour component, the average value for the block is calculated, as shown in step 930. The baseline value for each colour component is then determined by truncating the average value to say, three bits, as in step 935. Any discarded bits from the truncation process are held/stored, to be potentially used in modifying non-discarded bits. The colour component for each pixel is then set to be equal to the baseline value in step 940.

Preferably, if the baseline value has a binary value of '111' in step 945, the discarded bits are truly

discarded, and the process is repeated for the next block of pixels.

Otherwise, for each colour component, the least significant bit of the two bits discarded, when determining the baseline value, is assessed to see if it has a logical value of '1', in step 950. If this first, least significant bit of the two discarded bits has a logical value of '1' in step 950, a logical/binary '1' is added to the baseline value of the bottom right pixel in the block in step 955. In addition, if the second (LSB plus one) bit has a logical value of '1' in step 960, a logical/binary '1' is (also) added to the baseline value of each of the bottom left pixel and the top right pixel, as shown in step 965. The process is then repeated for the next block of pixels, as in step 970.

It will be appreciated that the pattern in which the baseline values are corrected dependant on the values of the discarded bits is only exemplary, and may be varied in any suitable manner. In fact, it is preferable for the pattern to be altered, for example flipped or rotated by 90 degrees, for each colour component in order to further redistribute the corrections throughout the block.

In embodiments that have a limited number of pixels within a block, the variation in how any corrections can be redistributed throughout the block is limited, especially for a block of '2x2'. When correcting two pixels, it is therefore preferable to correct two diagonally opposite pixels in order to avoid weighting one side.

A skilled artisan would appreciate that any display or video/image processing arrangement or video or image communication device that employs truncation or rounding down can benefit from the inventive concepts hereinbefore described. As such, the invention should not be viewed as being limited to the display, communication device or truncation of 16-bits to 9-bits, as described in the preferred embodiment.

The inventors of the present invention have also quantified examples of the improvements provided by the inventive concepts hereinbefore described. For example, root mean square bit errors (rmse) were calculated for both an original image truncated as normal, and one where the image was processed as described above.

Image truncated as normal:

rmse = 18.6(R) 19.3(G) 22.1(B);

as compared to the same image processed in accordance with the hereinbefore described inventive concepts:

rmse = 16.8(R) 17.6(G) 21.7(B).

Clearly, the error associated with the image processing is greatly improved using the hereinbefore-described inventive concepts. It is also noteworthy that by rotating the distribution of corrections for the different colour components the luminance rmse also improved, as illustrated below:

Image processed using the hereinbefore-described inventive concepts with a rotated distribution:

rmse = 13.2(L);

as compared to the same image processed using the hereinbefore described inventive concepts with a static distribution:

rmse = 13.9(L).

In summary, a method and apparatus for processing image or video data for a display have been described whereby a stream of image or video data is separated into a first sequence of pixel bit values for a colour component of the image or video and one or more discarded bits. A binary value of the one or more discarded bits is determined and the first sequence of pixel bit values is modified in response to the determined binary value of the one or more discarded bits. In this manner, a reduced number of pixel bit values is formed to represent the colour component of a pixel.

In the context of the present invention, the expression 'separating a stream of image or video data' should not be construed as being limited to real-time data. It is a feature of the present invention that the inventive concepts hereinbefore described applies equally to image data retrieved from a file stored in memory. It is also a feature of the present invention that the inventive concepts hereinbefore described apply equally to static images, since video images will require a higher quality of image, and so will use full 16-bit or 32-bit data.

It will be understood that the improved method of image processing described above provides at least the following advantages:

(i) Colour information discarded when truncating the colour components to, say, three bits is reused

within the block of pixels, improving the image quality and helping to significantly reduce effects such as contouring.

(ii) Improvement in image quality is achieved as all the advantages of using a truncation approach apply and, indeed, are enhanced.

Whilst the specific and preferred implementations of the embodiments of the present invention are described above, it is clear that one skilled in the art could readily apply variations and modifications of such inventive concepts.

Thus, a communication device with a display and method for improving a truncated image of a display have been described where the aforementioned disadvantages with prior art arrangements have been substantially alleviated.